national accelerator laboratory

EXP-23

September 12, 1972

ACCELERATOR EXPERIMENT--Radial Dependence of Tune in the Main Ring at 150 GeV

Experimentalists: R. Stiening

Date Performed: 3 & 5 September 1972

The data are appended to this report, followed by Stiening's plot of the tunes versus $\delta p/p$. The last page is a ν_y versus ν_x presentation of the data, with third order resonance lines sketched in.

We now have two high energy measurements of radial tune dependence. The first, at 74 GeV, was reported in EXP-22. Some initial comments about the two sets of data are in order; a more detailed discussion will appear in a later report.

First, let's look at ν_x versus $\delta p/p$. In EXP-22, we used an "eyeball" measure of the curvature to obtain an estimate of the octupole moment of the quadrupoles. Now, S. Ohnuma has done a least squares fit to second order in $\delta p/p$ for both the earlier data and the present measurements; he finds

$$\nu_x = 20.28 - 0.21\left(\frac{\delta p}{p}\right)_{\%} + 0.15\left(\frac{\delta p}{p}\right)^2_{\%} \quad \text{at 75 GeV}$$

$$\nu_x = 20.29 - 0.21\left(\frac{\delta p}{p}\right)_{\%} + 0.23\left(\frac{\delta p}{p}\right)^2_{\%} \quad \text{at 150 GeV}$$

His result at 75 GeV indicates a larger octupole moment than that deduced in EXP-22, though within the limits of uncertainty of that report. The 150 GeV fit implies an octupole moment still larger by a factor of more than 1.5. As designed, the main ring quadrupoles should not exhibit an increase of positive octupole moment with excitation. A more likely source of the difference is a radial dependence of the curvature. A comparison of the RF system frequencies for $\delta p/p = 0$ in the two sets of data indicates the lower energy data explored a region shifted to smaller radius by about 0.1% in $\delta p/p$. Thus the curvature seems to increase with increasing radius. Indeed, the plot at 150 GeV does appear to become more linear at smaller momentum. We conclude that it is an over-simplification to try to account for the high energy radial tune dependence by solely the chromatic aberration of the quadrupoles and their octupole moment.

Second, consider ν_y versus $\delta p/p$. Ohnuma's fit to the 150 GeV data is

$$\nu_y = 20.18 - 0.26\left(\frac{\delta p}{p}\right)_{\%} - 0.036\left(\frac{\delta p}{p}\right)^2_{\%} \qquad 150 \text{ GeV}$$

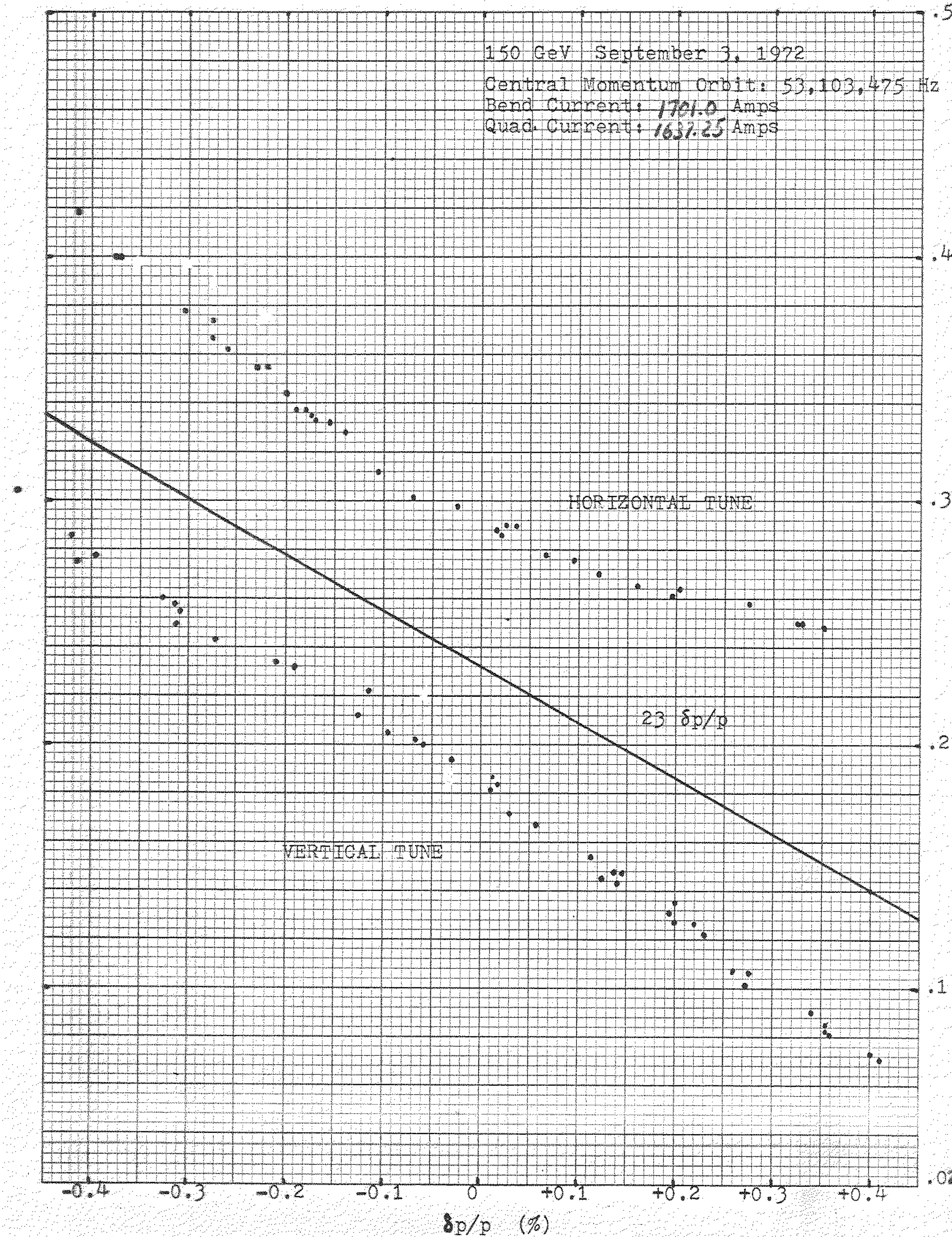
As calculated in EXP-22, the second order term in $\delta p/p$ for vertical motion should be only some 4% of the corresponding term for radial motion if those terms arise from the octupole moment of the quadrupoles. The coefficient above, $-.036$, is too large by a factor of four and is of the wrong sign. Again, we are forced to conclude that our model is too simple. In fact, the vertical plot looks rather like two straight lines, intersecting at $\delta p/p = 0$.

Third, the ν_y versus ν_x plot exhibits a discontinuity in slope at $\delta p/p = 0$. Again, we have the intersection of two straight lines, whereas chromatic aberration and an octupole moment common to all the quads would result in a parabola.

Finally, though the trajectory on the ν_y versus ν_x plot crosses a number of third order resonance lines, only at $2\nu_y - \nu_x = 20$

was there an observable effect -- in particular the vertical oscillation excited by the pinger was seen to damp in 60 turns in contrast to continuing for a long time. This coupling resonance would arise from a twentieth harmonic of a sextupole moment, and given an octupole moment in the quads, the twentieth harmonic of the closed orbit distortion (which we know to exist) will produce a twentieth sextupole harmonic.

D. A. Edwards


150 GeV September 3, 1972
Central Momentum Orbit: 53,103,475 Hz
Bend Current: 1701.0 Amps
Quad Current: 1637.25 Amps
HORIZONTAL TUNE
23 δp/p
VERTICAL TUNE
.5
.4
.3
.2
.1
.02
-0.4
-0.3
-0.2
-0.1
0
+0.1
+0.2
+0.3
+0.4
δp/p (%)

150 GeV   September 3, 1972

Bend Current: 1791.0 Amps
Quad Current: 1631.25 Amps

Central Momentum Orbit Frequency: 53,103,475 Hz

VERTICAL TUNE

δp/p (%)	v_y	
-0.422	26/91	20.286
-0.312	23/92	20.250
-0.310	23/90	20.255
-0.115	20/91	20.220
-0.060	18/90	20.200
+0.015	17/91	20.187
+0.018	16/87	20.184
+0.113	14/91	20.154
+0.138	13/88	20.148
+0.145	14/95	20.1475
+0.200	6/47	20.1275*
+0.200	8/59	20.135*
+0.220	12/94	20.1275*
+0.260	10/93	20.1075
+0.275	10/93	20.1075
+0.355	7/85	20.0825
+0.420	6/84	20.0715

*Oscillation damped in 60 turns

HORIZONTAL TUNE

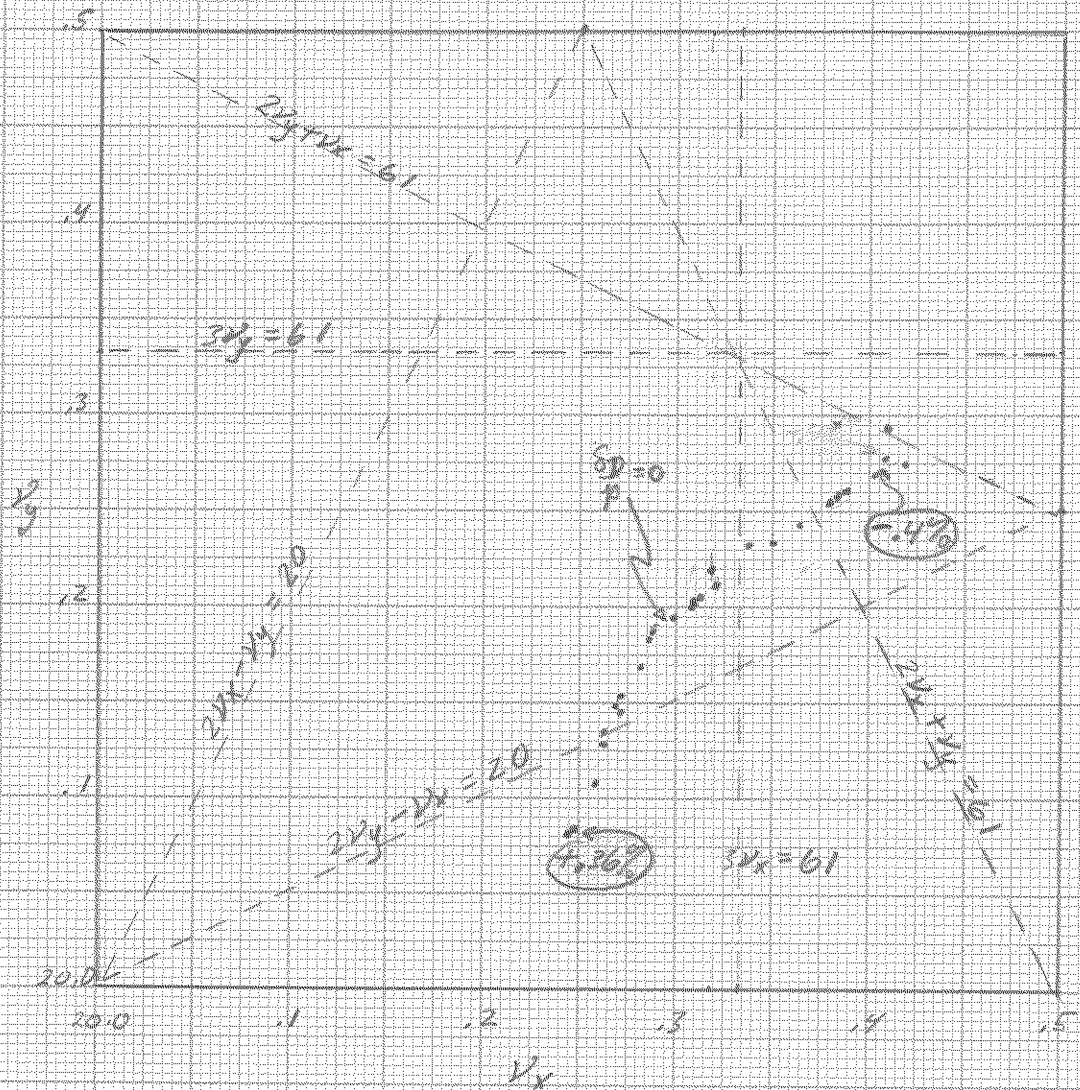
δp/p (%)	v_x	
-0.415	38/91	20.418
-0.378	36/90	20.400
-0.372	36/90	20.400
-0.302	34/90	20.378
-0.275	34/91	20.374
-0.275	33/90	20.367
-0.260	34/94	20.362
-0.226	33/93	20.355
-0.220	33/93	20.355
-0.200	32/93	20.344
-0.190	32/95	20.337
-0.180	32/95	20.337
-0.175	32/95.5	20.335
-0.170	31/93	20.333
-0.155	31/93.5	20.332
-0.140	31/94.5	20.328
-0.105	29/93	20.312
-0.070	29/94	20.308
-0.025	28/94	20.298
+0.015	27/94	20.288
+0.020	26/91	20.286
+0.025	27/93	20.290
+0.036	27/93	20.290
+0.068	26/93.5	20.278
+0.095	25/90.5	20.276
+0.120	24/89	20.270
+0.160	25/94.5	20.265
+0.196	24/92	20.261
+0.204	24/91	20.264
+0.275	23/89	20.258
+0.325	23/92	20.250
+0.328	22/88.5	20.249
+0.351	23/93	20.247

150 GeV   September 5, 1972

Bend Current: 1701.0 Amps
Quad Current: 1637.25 Amps
Central Momentum Orbit Frequency: 53,103,475 Hz

VERTICAL TUNE

$\delta p/p$ (%)	ν_y		frequency
-0.728	33/93	20.355	53,104,461
-0.660	32/95	20.337	53,104,369
-0.590	30/95	20.316	53,104,274
-0.571	30/92	20.326	53,104,248
-0.480	28/92.5	20.303	53,104,135
-0.418	26/94.5	20.275	53,104,036
-0.396	26/94	20.277	53,104,012
-0.329	25/96.5	20.260	53,103,921
-0.314	24/93	20.258	53,103,900
-0.271	23/94.5	20.243	53,103,842
-0.210	22/94	20.234	53,103,762
-0.190	21/90.5	20.232	53,103,735
-0.122	19/89.5	20.212	53,103,642
-0.095	19/93	20.205	53,103,605
-0.068	19/94	20.202	53,103,568
-0.030	18/93	20.194	53,103,518
+0.010	17/94	20.181	53,103,461
+0.030	16/93	20.172	53,103,434
+0.058	15/90	20.167	53,103,397
+0.125	12/83	20.145	53,103,308
+0.140	13/91	20.143	53,103,283
+0.195	12/92	20.131	53,103,210
+0.230	11/90.5	20.122	53,103,166
+0.272	9/82.5	20.110	53,103,108
+0.340	8/89.5	20.090	53,103,013
+0.358	7/86	20.081	53,102,989
+0.400	6/82	20.073	53,102,933



150 GeV 3 Sept 1972
& 5 Sept 1972